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## **NASA's Bio-inspired Broadband Acoustic Absorber: Technology for Quieter Transportation**

L. Danielle Koch, M.S., P.E.  
Aerospace Engineer  
NASA Glenn Research Center, Acoustics Branch



# NASA's Bio-inspired Broadband Acoustic Absorber

## Outline

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### Outline

- Visual abstract
- Motivation
- Problem definition
- Inspiration from nature
- Concept description
- Common automotive and aviation noise challenges and opportunities
- Selected publications and presentations
- Educational outreach resources
- Executive summary
- Acknowledgements
- Contact information



# NASA's Bio-inspired Broadband Acoustic Absorber

## Visual abstract

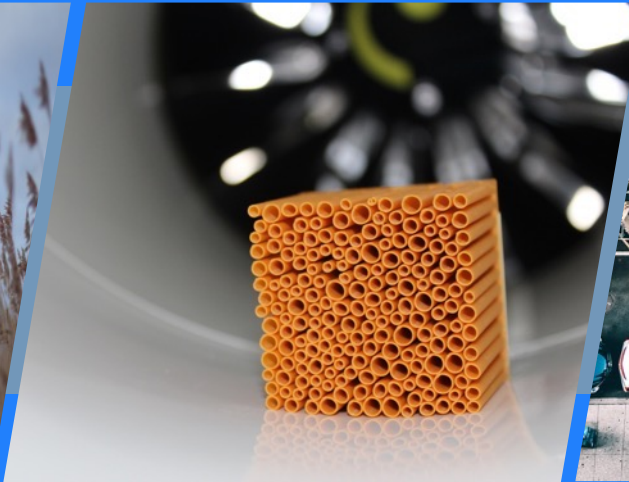
*Motivated to  
reduce aircraft  
noise  
pollution...*



*...inspired  
by natural  
reeds...*



*...NASA has patented a  
Bio-inspired Broadband  
Acoustic Absorber....*



*...that can be developed for many  
transportation noise control  
applications, particularly those  
with harsh operating conditions.*



*Proof-of-concept tests show that synthetic structures resembling bundles of natural reeds offer an increase in sound absorption at frequencies below 1000 Hz compared to state-of-the-art commercially available structures of similar thickness and weight.*



# NASA's Bio-inspired Broadband Acoustic Absorber

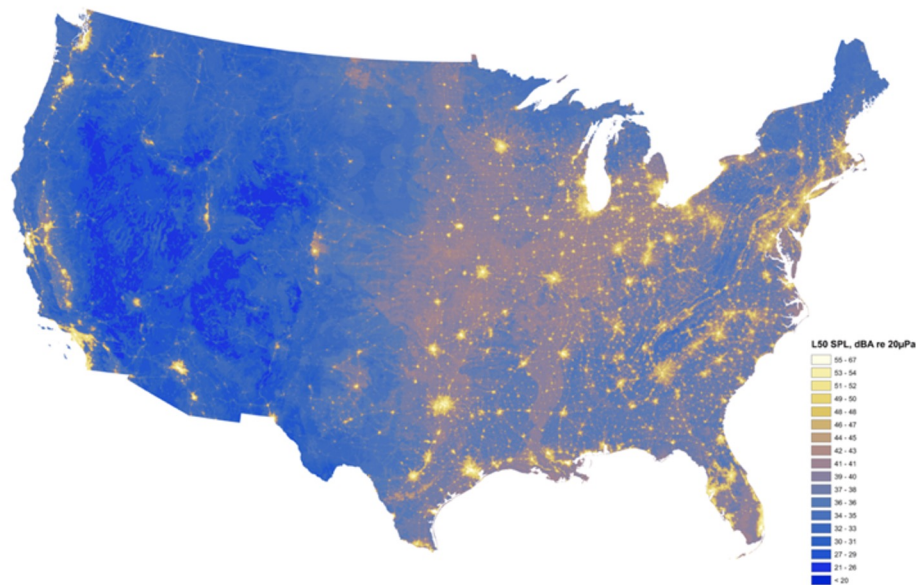
## Motivation

### From the U. S. National Park Service:

“Pervasive flight traffic coupled with an extensive road network eliminates natural quiet across almost the entire country. Only 12% of the country has an impact of 1.4 dBA or less.”

Source: Mennitt, D., Fristrup, K. M., Sherrill, K., Nelson, L. “Mapping sound pressure levels on continental scales using a geospatial sound model.” Proceedings of InterNoise 2013, 2013.

Mapping Sound: Existing conditions



# NASA's Bio-inspired Broadband Acoustic Absorber

## Motivation

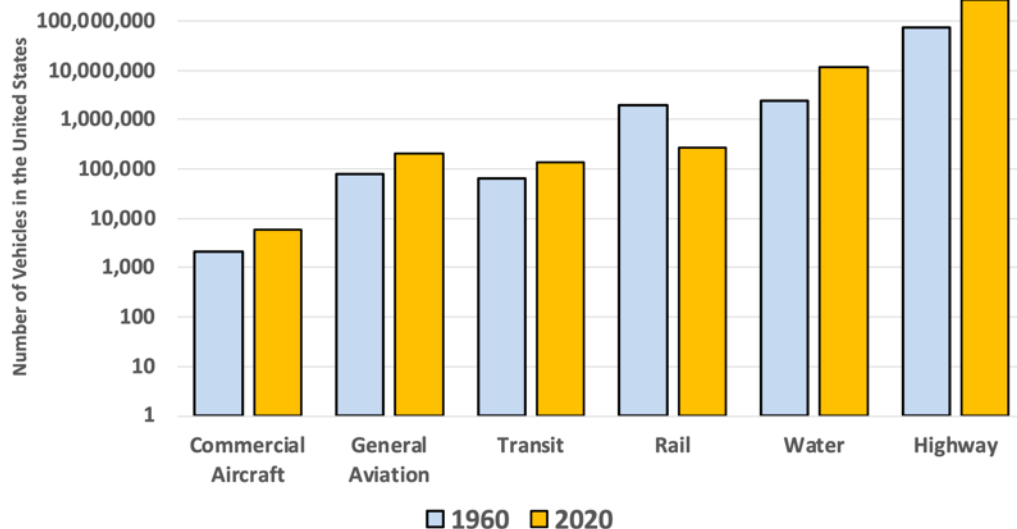
### From the U.S. Department of Transportation:

Since the 1960's, the number of vehicles on land, sea, and air in the United States has roughly tripled.

Source: U.S. Department of Transportation, Bureau of Transportation Statistics, "Table 1-11: Number of U.S. Aircraft, Vehicles, Vessels, and Other Conveyances." 2023.

<https://www.bts.gov/content/number-usaircraft-vehicles-vessels-and-other-conveyances>.

Number of Vehicles in the United States, 1960-2020



# NASA's Bio-inspired Broadband Acoustic Absorber

## Motivation

### From the U.S. Department of Transportation:

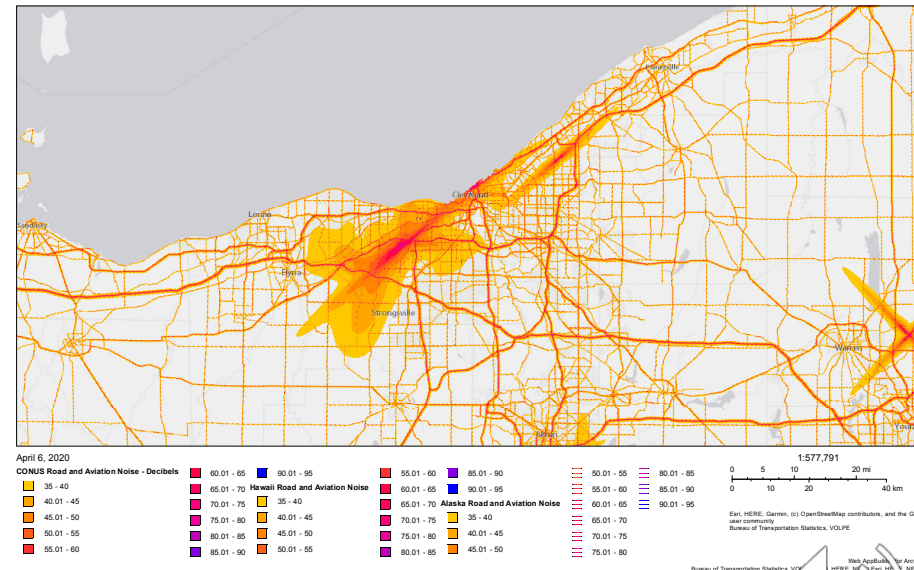
Aircraft noise is concentrated near our airports and is audible for nearly everyone in the US.

You can explore soundscape trends in your neighborhood using the online National Transportation Noise Map.

Source: United States Department of Transportation, Bureau of Transportation Statistics, "National Transportation Noise Map," 2020.

### US Department of Transportation National Transportation Noise Map: Road and Aviation Noise Near Cleveland, OH

ArcGIS Web Map

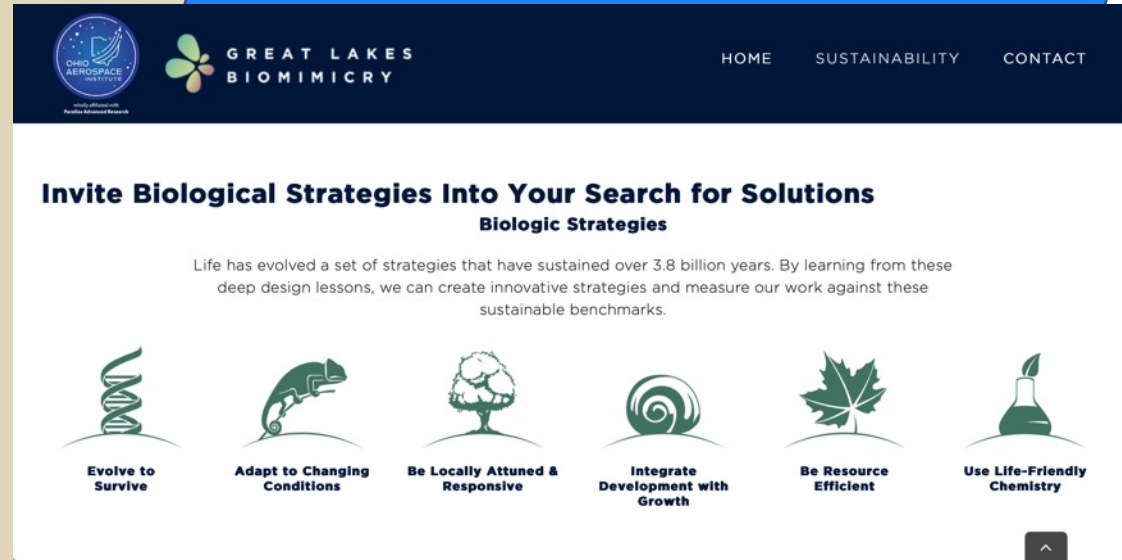


# NASA's Bio-inspired Broadband Acoustic Absorber

## Motivation

From Great Lakes Biomimicry at the Ohio Aerospace Institute:

“Biomimicry is innovation inspired by nature.”



# NASA's Bio-inspired Broadband Acoustic Absorber

## *Problem definition*

**From the National Aeronautics and Space Administration:**

NASA research teams are asking:

How might we develop a commercial air transportation system accessible to a growing population that is cleaner, safer, and quieter than the one we have today?

Illustrations of some  
concept aircraft

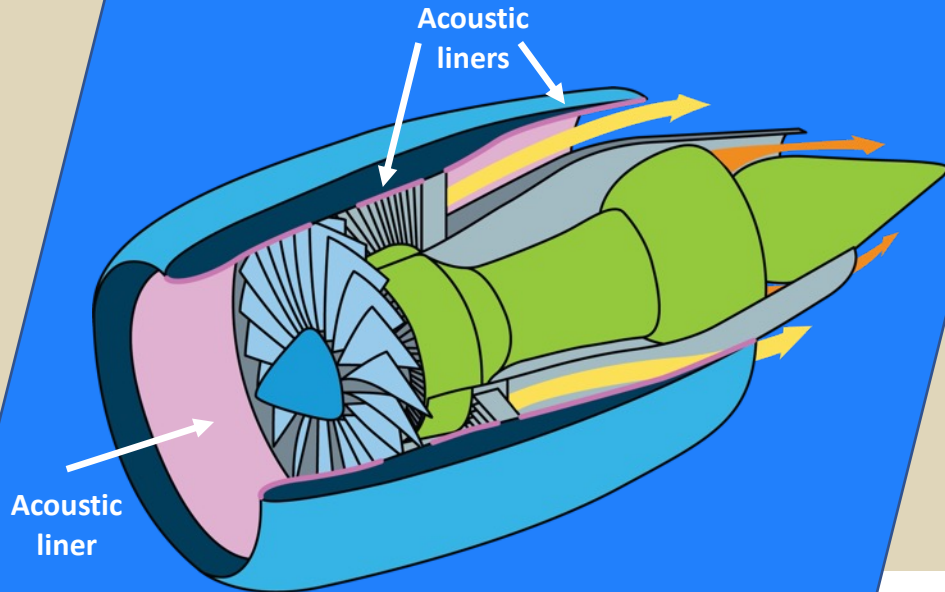


# NASA's Bio-inspired Broadband Acoustic Absorber

## *Problem definition*

**From the National Aeronautics and Space Administration:**

We need to continue to integrate acoustically absorbent liners into aircraft engines and fuselages of all types.



Aircraft engine acoustic liners, shown here in pink, are used to absorb sounds from many places inside turbofan engines.



# NASA's Bio-inspired Broadband Acoustic Absorber

## *Problem definition*

### From the National Aeronautics and Space Administration:

Acoustic liners are used inside turbofan engines today. Some liners are placed upstream of the bypass fan. Liners absorb sounds from inside the engine, reducing the aircraft noise heard by passengers and crew onboard the aircraft and by people and wildlife near the aircraft on the ground or living beneath the flight path.



Aircraft engine acoustic liners are placed inside the nacelle and are used to absorb sounds from inside the engine.



# NASA's Bio-inspired Broadband Acoustic Absorber

## *Problem definition*

Under the perforated surface of today's aircraft engine acoustic liners, you might see one or more layers of honeycomb. Perforate-over-honeycomb acoustic liners are structures that resonate and can absorb sound during flight while also surviving the engine operating conditions.

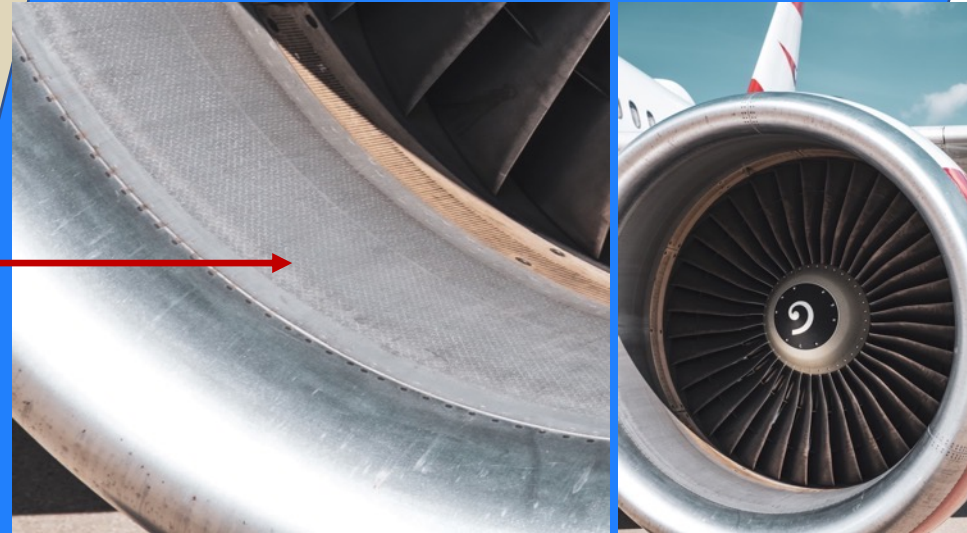
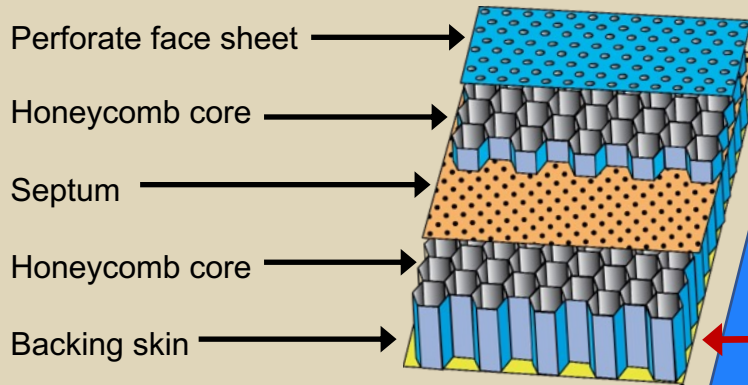



Illustration of Double-Degree of Freedom Perforate-Over-Honeycomb Aircraft Engine Acoustic Liner



# NASA's Bio-inspired Broadband Acoustic Absorber

## *Problem definition*

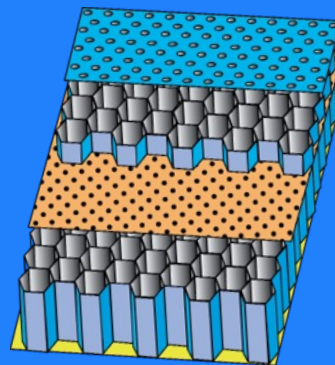
Melamine foam is one of the most popular types of commercially available acoustic absorber in the market today. 

These of lightweight porous materials tend to absorb water and oil and are not durable enough for aircraft engine noise control.

While both styles of acoustic absorbers are impressive, neither are perfect.

We are looking for improved acoustic liners for aircraft engines.

NASA turned to nature for inspiration.



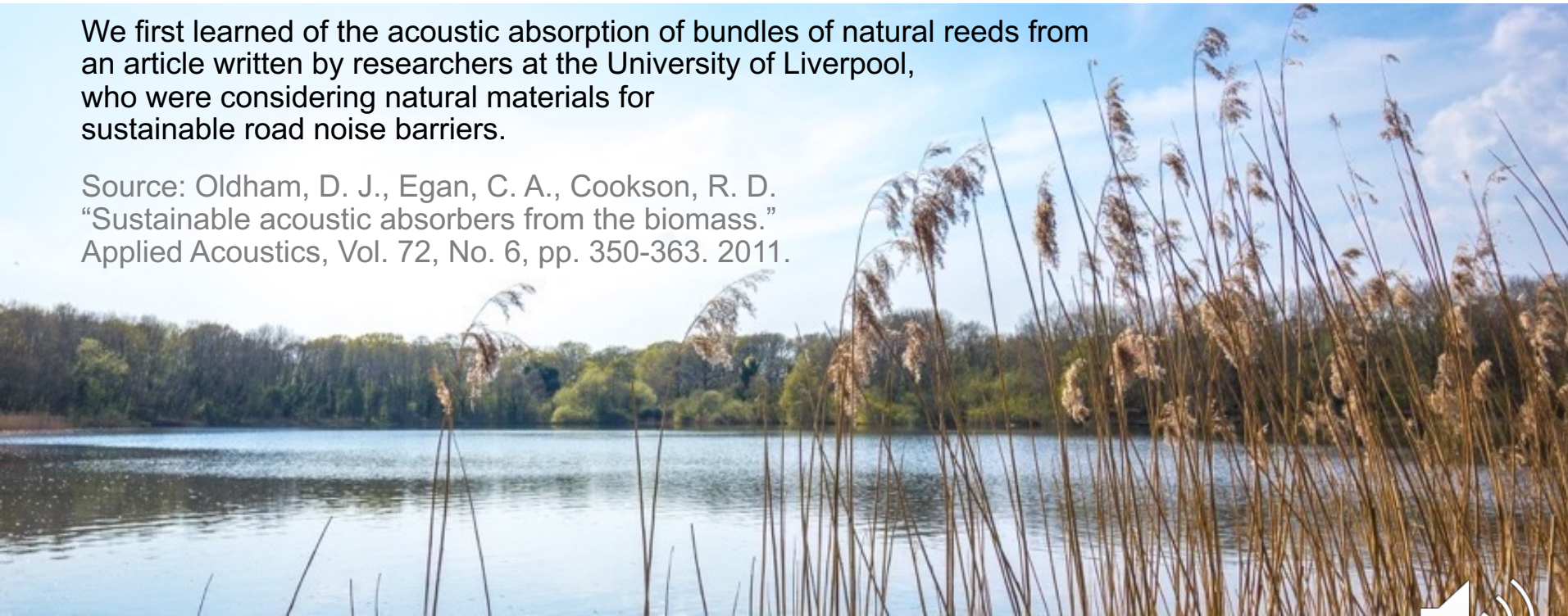
# NASA's Bio-inspired Broadband Acoustic Absorber

## *Inspiration from nature*

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We first learned of the acoustic absorption of bundles of natural reeds from an article written by researchers at the University of Liverpool, who were considering natural materials for sustainable road noise barriers.

Source: Oldham, D. J., Egan, C. A., Cookson, R. D.  
“Sustainable acoustic absorbers from the biomass.”  
Applied Acoustics, Vol. 72, No. 6, pp. 350-363. 2011.



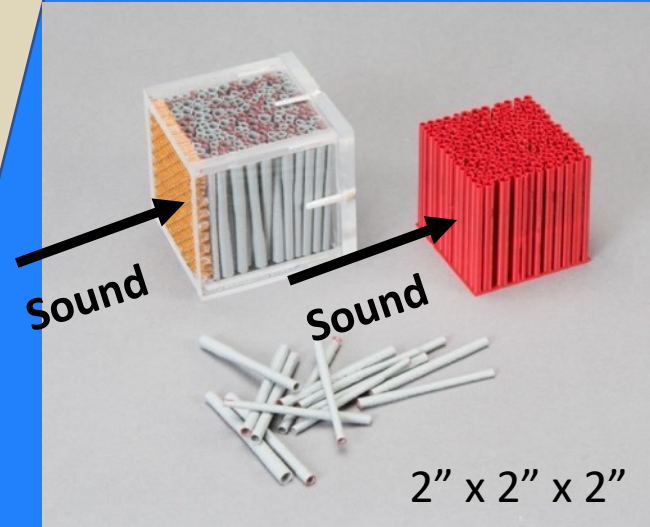
# NASA's Bio-inspired Broadband Acoustic Absorber

## Concept description

That inspiration led us to design and additively manufacture plastic prototypes that resembled bundles of natural reeds.



Dried natural reeds



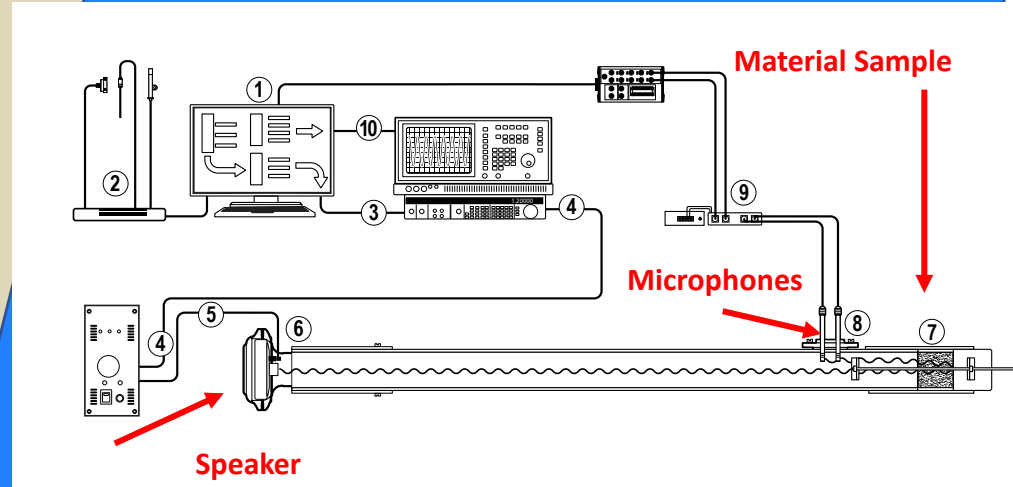
3D Printed Plastic "reeds"



# NASA's Bio-inspired Broadband Acoustic Absorber

## Concept description

This first proof-of-concept data were acquired in the the NASA GRC and LaRC normal incidence impedance tubes.



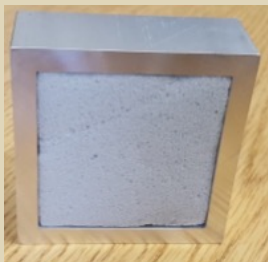
NASA GRC Normal Incidence Impedance Tube  
2" x 2" Square Cross-section  
400-3000 Hz Testing Range

# NASA's Bio-inspired Broadband Acoustic Absorber

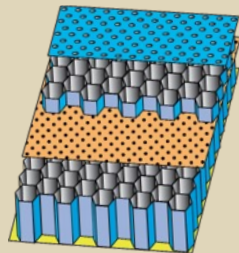
## Concept description

Both baseline acoustic absorbers performed well, absorbing most sound above 1000 Hz in normal incidence tube tests.

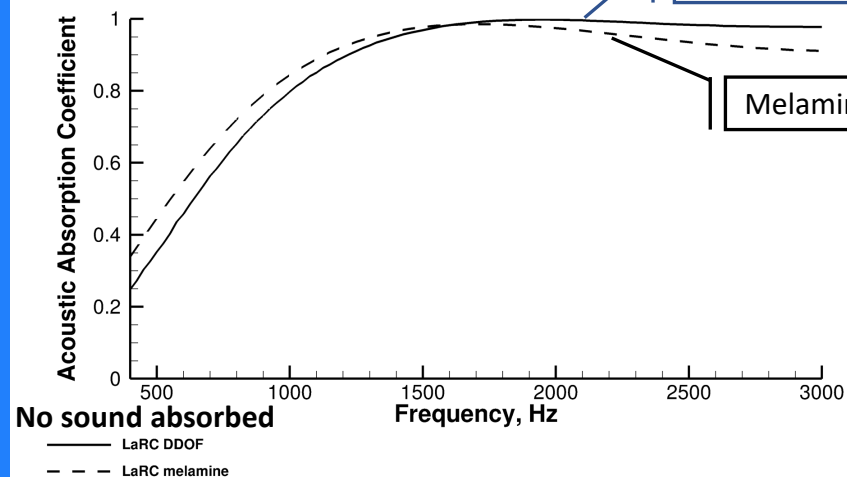
Melamine



DDOF-POHC



All sound absorbed



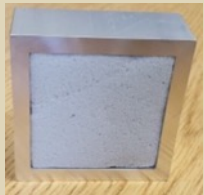
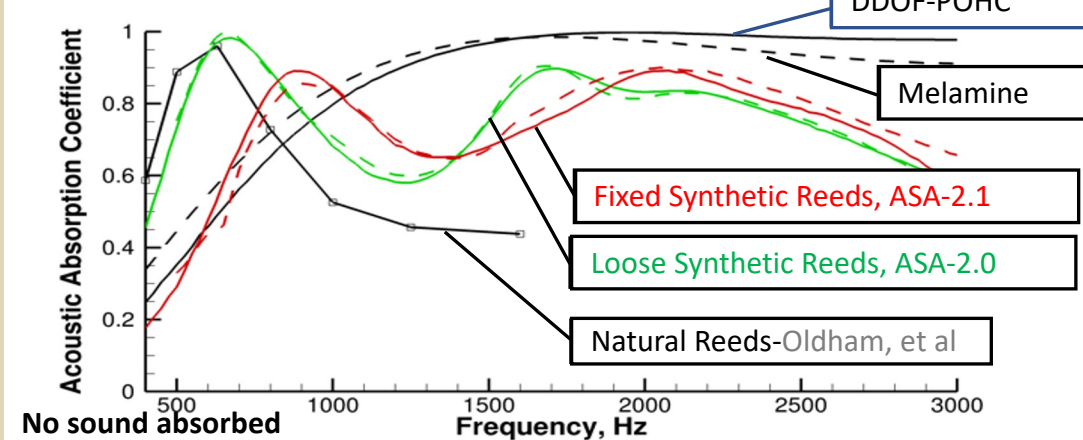
# NASA's Bio-inspired Broadband Acoustic Absorber

## Concept description

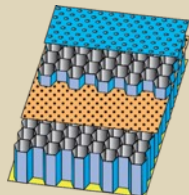
The prototypes that resembled bundles of natural reeds absorbed more sound below 1000 Hz compared to the baselines, and similar to the natural reeds.

These samples were ~ 2" thick.

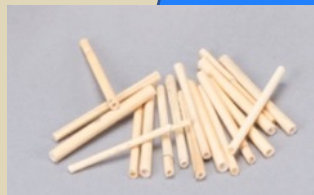
All sound absorbed



Melamine



DDOF-POHC.



Dried Natural Reeds



Loose Synthetic



Fixed Synthetic

# NASA's Bio-inspired Broadband Acoustic Absorber

## *Automotive noise control challenges*

### From the National Aeronautics and Space Administration:

NASA Technology Transfer teams are inviting others to think more broadly:

Can technology patented by NASA be developed into a wide range of automotive, industrial, marine, and architectural noise control products beyond aerospace use?

There are thousands of examples of NASA 'spinnoff' technology catalogued on the web and in print at: <http://spinnoff.nasa.gov>

What are the aviation and automotive noise control challenges?



<https://spinnoff.nasa.gov/spinnoff/archives>

# NASA's Bio-inspired Broadband Acoustic Absorber

## Automotive and aviation noise challenges and opportunities

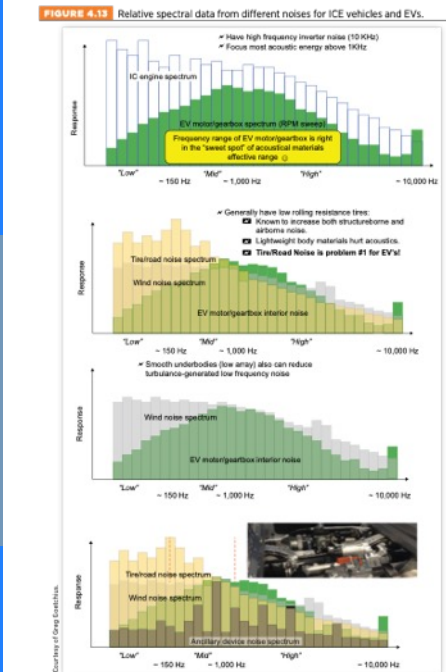
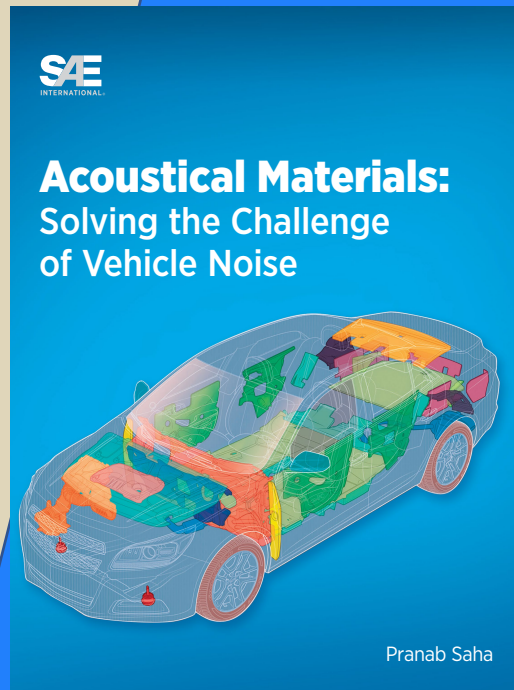
### From SAE Publications:

“Road/Tire noise is problem #1 for EV’s”

Acoustic liner material is used in many parts of a vehicle. The road/tire noise spectrum indicates that broadband noise reduction strategies are needed, especially below 1000 Hz.

Sources: Acoustical Materials: Solving the Challenge of Vehicle Noise, Saha, Pranab, SAE International, 2021 (pg 88) which cites:

Goetchius, G., “EV Powertrain NVH,” Presented at the SAE vehicle Noise Control Engineering Academy ACAD01 and ACAD02 ,Vehicle Interior Noise and Powertrain Noise Tracks, SAE Noise Academy, Sept 30 – Oct 4, 2019.



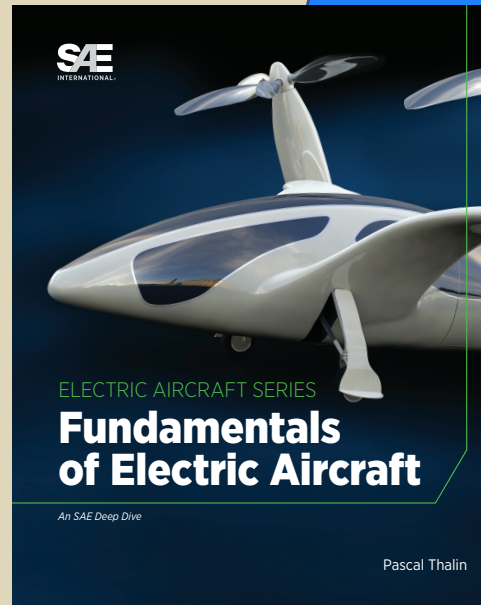
# NASA's Bio-inspired Broadband Acoustic Absorber

## *Automotive and aviation noise challenges and opportunities*

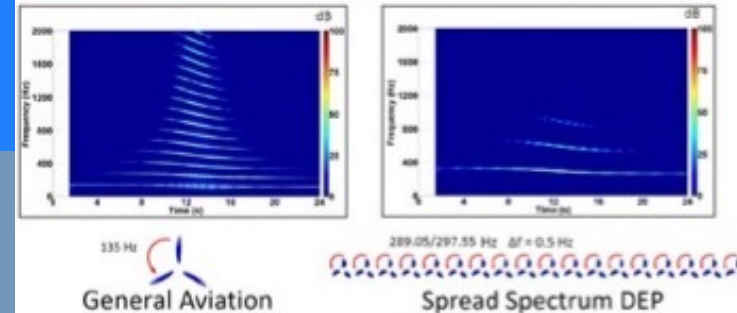
### From SAE Publications:

“All-electric aircraft allow outright elimination of combustion engine noises offering drastic noise reductions. **Figure 10.32** shows how, in the case of general aviation, distributed electric propulsion helps alleviate noise issues by enabling sound reduction methods such as “reduced propulsor tip speed” and “spread spectrum,” among others.”

Source: Fundamentals of Electric Aircraft, Pascal Thalin, SAE, 2018.



**FIGURE 10.32** General Aviation noise performance (turboprop vs. DEP) [10.25].



Tools for Assessing Community Noise of DEP Vehicles, Stephen A. Rizzi, NASA Langley Research Center, Highly Integrated Distributed Electrical Propulsion Tool and Testing Panel Discussion, AHS-AIAA Transformative Vertical Flight Concepts Joint Workshop on Enabling New Flight Concepts through Novel Propulsion and Energy Architectures, Arlington, VA, USA, August 26-27, 2014.

# NASA's Bio-inspired Broadband Acoustic Absorber

## *Automotive and aviation noise challenges and opportunities*

### From NASA Publications:

“The SUSAN trade space exploration intends to define an aircraft configuration that uses a combination of a hybrid [Electrified Aircraft Propulsion] EAP system, advanced propulsion aircraft integration (PAI), and alternative fuels to fulfill its mission... The target market application is the regional jet class of transport aircraft. The key performance metrics are total energy use, emissions, noise, and total cost of ownership.”

Source: Jansen, R., et al., “Subsonic single aft engine (SUSAN) transport aircraft concept and trade space exploration, AIAA-2022-2179, 2022.



Subsonic Single Aft Engine (SUSAN) Concept Aircraft



SUSAN V0



SUSAN V1



SUSAN V2



SUSAN V3



# NASA's Bio-inspired Broadband Acoustic Absorber

## *Automotive and aviation noise challenges and opportunities*

### From NASA Publications:

“One of the barriers to achieving the full benefits of EAP is the thermal management of the electrical components. The thermal management challenge for the SUSAN Electrofan aircraft concept is particularly challenging because the amount of low-grade waste heat generated by the electronics is an order of magnitude higher than that of any existing aircraft.”

Source: Jansen, R., et al., “Subsonic single aft engine (SUSAN) transport aircraft concept and trade space exploration, AIAA-2022-2179, 2022.

### Subsonic Single Aft Engine (SUSAN) Concept Aircraft

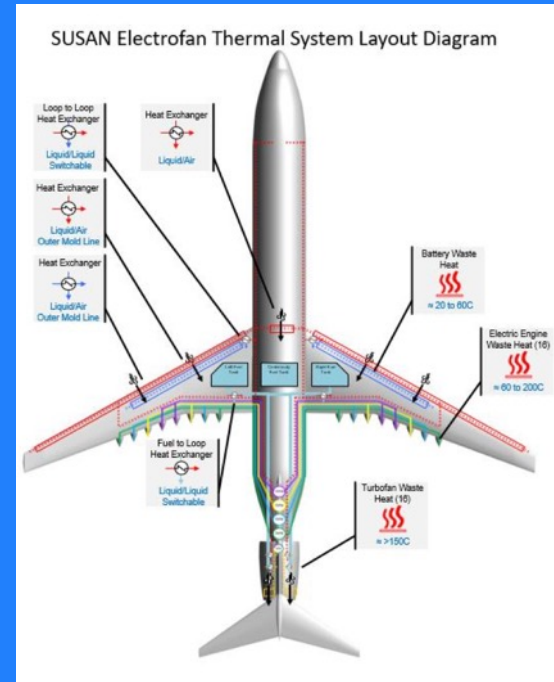


Image Credits: NASA

# NASA's Bio-inspired Broadband Acoustic Absorber

## *Automotive and aviation noise challenges and opportunities*

### From NASA Publications:

“NASA’s research team is asking even more ambitious questions, like....

How might we create thin, lightweight, multifunctional structures to transfer heat, carry a load and absorb broadband noise especially below 1000 Hz while also surviving harsh operational conditions such as exposure to sprays of liquids and solid debris, and high temperatures.

New materials will be needed to enable electric and hybrid-electric flight.”

Source: Sutliff, D., et al., “Collaboration with Williams International to Demonstrate the Characteristics of a Foam-Metal-Liner Installed Over-the-Rotor of a Turbofan Engine,” 2008.



Foam metal acoustic liners were tested in a Williams International aircraft engine in the NASA Glenn AeroAcoustic Propulsion Laboratory



# NASA's Bio-inspired Broadband Acoustic Absorber

## *Automotive and aviation noise challenges and opportunities*

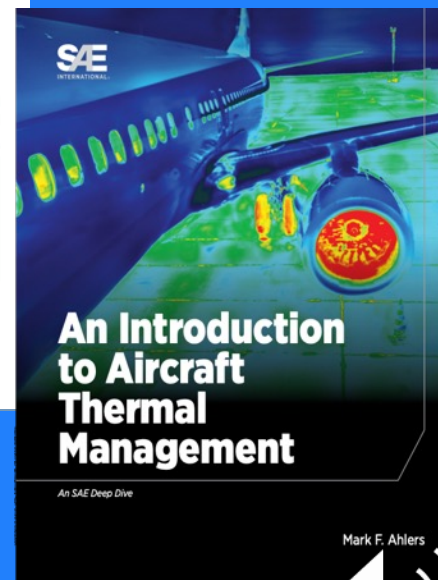
### From SAE Publications:

“Automotive emission reduction and fuel economy are high on the agenda of government regulatory bodies in an ongoing effort to improve engine performance and reduce environmental pollution. One key way to accomplish these goals is through a well-developed thermal management system.”

Thermal Management in Automotive Applications, T. Yomi Obidi, SAE, pg. 7, 2015.

“The waste heat low temperatures are the biggest hindrance to energy recovery. Consequently, in the near term transferring almost all waste heat to either *ambient air* or *fuel* is the only practical option for thermal management.”

Source: An Introduction to Aircraft Thermal Management, Mark Ahlers, SAE, pg. 67, 2019.

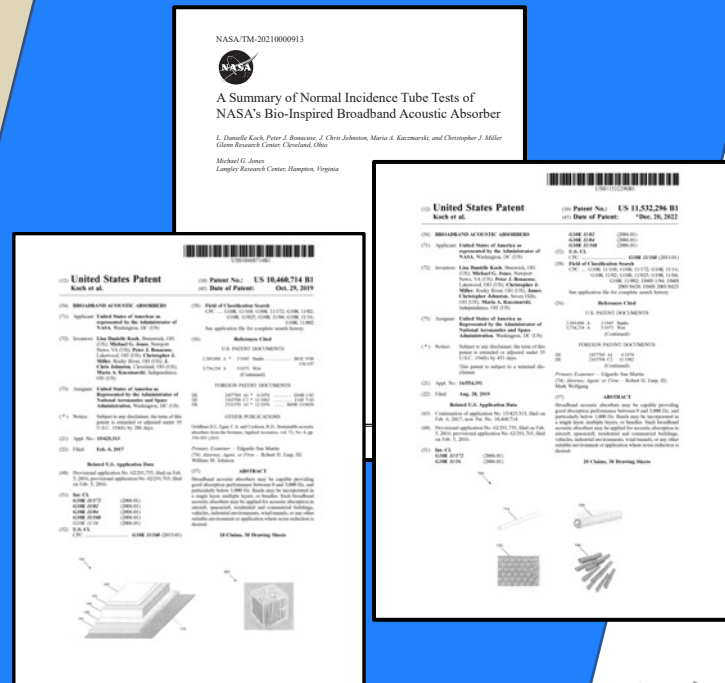


# NASA's Bio-inspired Broadband Acoustic Absorber

## Selected Publications

### Articles and patents

1. **An Introduction to NASA's Broadband Acoustic Absorbers that Resemble Natural Reeds**, Koch, Jones, Bonacuse, Miller, Johnston, Kuczmarski, *International Journal of Aeroacoustics*, Vol. 20, Issue 5-7, p 662-679, Sept. 2021.
2. **A Summary of Normal Incidence Tube Tests of NASA's Bio-inspired Broadband Acoustic Absorber**, Koch, Bonacuse, Johnston, Kuczmarski, Miller, Jones NASA-TM-2021-0000913, 2021.
3. **Broadband Acoustic Absorbers**, Koch, Jones, Bonacuse, Miller, Johnston, Kuczmarski, US 10,460,714 B1, United States Patent and Trademark Office, 2019.
4. **Broadband Acoustic Absorbers**, Koch, Jones, Bonacuse, Miller, Johnston, Kuczmarski, US 11,532,296 B1, United States Patent and Trademark Office, 2022.



# NASA's Bio-inspired Broadband Acoustic Absorber

## *Selected Publications*

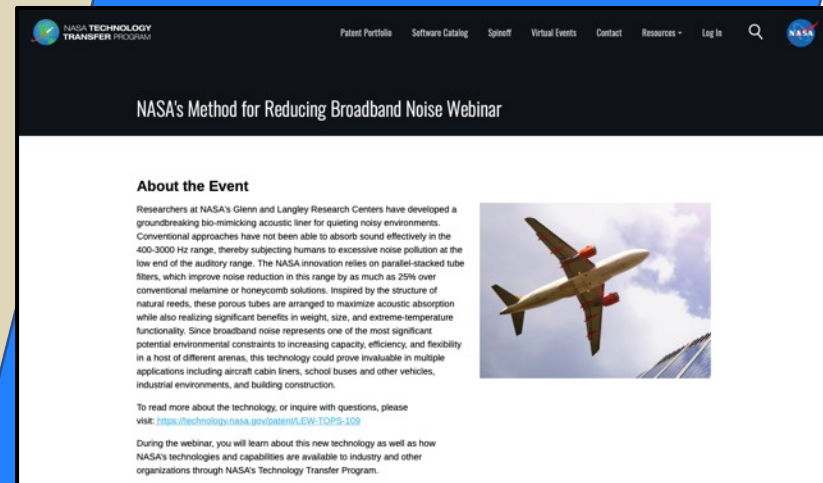
### **Presentations**

5. **NASA's Bio-inspired Acoustic Absorber: An Inventive Journey Towards Peace and Quiet**, Koch, presented at Biocene 2022: Transformation of Transportation, Ohio Aerospace Institute, May 18-20, 2022, Document ID 20220005593, 2022.

6. **NASA's Method to Reduce Broadband Noise Webinar**; NASA's Bio-inspired Broadband Acoustic Absorber: Technology for a Quieter World, NASA Technology Transfer Virtual Events Series, Koch, <https://technology.nasa.gov/virtual-event/nasa-method-reducing-broadband-noise-webinar> (Accessed March 15, 2023).

7. **NASA's Bio-inspired Broadband Acoustic Absorber: Experiences at the 2021 FedTech Startup Studio**, Koch, presented at the NASA Acoustics Technical Working Group meeting, April 12-13, 2022, Document ID 20220004378, 2022.

### NASA's Technology Transfer Program Virtual Events Series



<https://technology.nasa.gov/virtual-events>

# NASA's Bio-inspired Broadband Acoustic Absorber

## *Educational outreach resources*

Details available online for:

### [Xploration Nature Knows Best video interview](#)

Filmed in the NASA GRC AeroAcoustic Propulsion Laboratory

### [NASA GRC High School Capstone Projects](#)

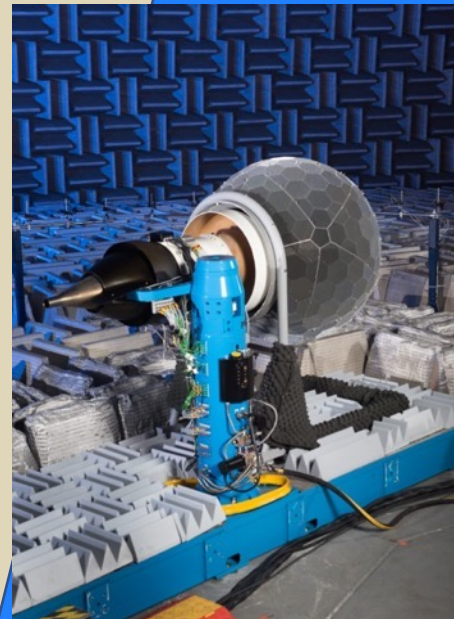
The 'Acoustic Damping' project has been one of the most popular projects since 2017.

### [NASA ARMD Leveled Reader Series](#)

Biographies that describe NASA research, the bioliner, and aerospace engineering careers for people learning how to read.

### [Stepping Stars: A Multi-State Middle and High School Space Grant STEM Engagement Project](#)

Students will be introduced to the concepts of biomicry.



Xploration Nature Knows Best host Danni Washington and NASA engineers Dan Sutliff and Danielle Koch in the AeroAcoustic Propulsion Laboratory with the DGEN Aeropropulsion Research Turbofan.



# NASA's Bio-inspired Broadband Acoustic Absorber

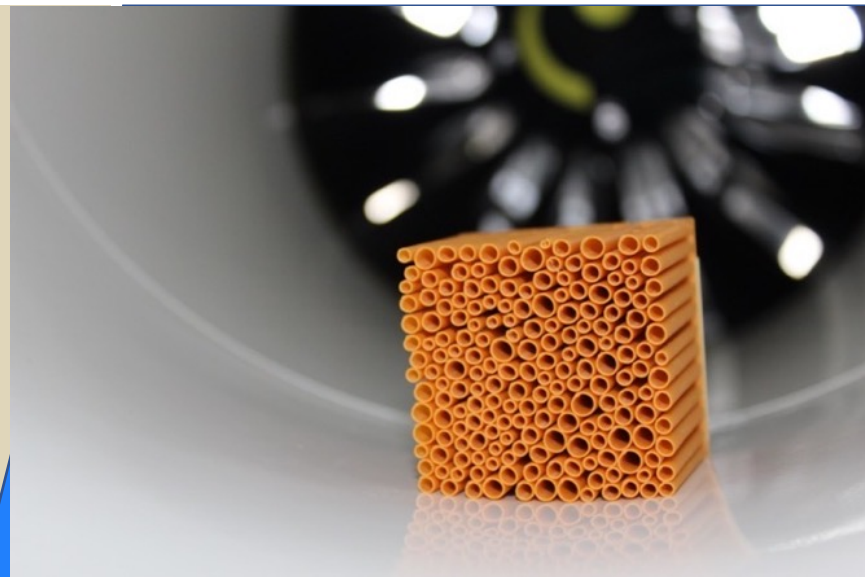
## *Executive summary*

NASA has patented a Bio-inspired Broadband Acoustic Absorber ('bioliner') and is developing it for aircraft engines.

We are claiming that these structures can also be used for a wide range of automotive, architectural, industrial, and marine noise control applications.

Bioliners have the potential to be developed into multifunctional structures that can absorb sound and might transfer heat, carry a load, and/or some other function, needed to enable more-electric transportation.

Experiments demonstrate that these synthetic structures resembling bundles of natural reeds offer an increase in sound absorption at frequencies below 1000 Hz compared to state-of-the-art structures of similar thickness and weight.



**A 'Bioliner' prototype placed in the  
NASA Glenn Research Center  
DGEN Aeropropulsion Research Turbofan Engine inlet**



# NASA's Bio-inspired Broadband Acoustic Absorber

## Acknowledgements

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### NASA Glenn Research Team

**Danielle Koch**, Acoustics Branch

**Chris Miller**, Acoustics Branch (retired)

**Dan Sutliff**, Acoustics Branch

**Ed Envia**, Acoustics Branch

**Jeffrey Severino**,

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**Amy Jankovsky**, Power and Propulsion Subproject Manager

**Jessica Reinert**, Power and Propulsion Deputy  
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**Christie Funk**, NASA Headquarters

**Jeanne King**, NASA GRC



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Thank  
you!

For questions about NASA's Bio-inspired  
Broadband Acoustic Absorber, please contact:

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